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# Growth Responses of Chicks Fed Microbial Protein Produced from Organic Wastes

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The objective of this study was to investigate the use of microbial protein produced from organic wastes as a source of protein in chick starting rations.

Microbial protein recovered from the mold mycelia was produced when potato waste materials were homogenized and added to a mineral salt containing a culture medium suitable for the action of a strain of Aspergillus niger.

The new product containing approximately 20.0 percent protein was added to chick starting rations, replacing the soybean protein. Sixty-two percent (62%) of the protein in the ration were supplied by soybean meal. The length of the feeding trial was four (4) weeks.

Results of the feeding trials showed that fungal protein was effective in supporting body maintenance but was ineffective in stimulating growth. Palatability of rations and poor feed consumption were factors contributing to slow growth. However, feed utilization was less of a problem as shown by nitrogen retention trials.


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by

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## FOREWORD

*The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.*

*Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.*

*The object of this study was to determine if fungal protein produced from the biotransformation of organic wastes could be substituted for conventional protein in chick starting diets. Results of the feeding trial clearly showed that fungal protein when added as a replacement for soybean protein, supported chick body maintenance but was not as effective as the standard protein diet in stimulating growth. Palatability of ration and poor feed consumption were factors contributing to slow growth.*

*Francis T. Mayo*
*Director*
*Municipal Environmental Research*
*Laboratory*

## ABSTRACT

*The objective of this study was to investigate the use of microbial protein produced from organic wastes as a source of protein in chick starting rations.*

*Microbial protein recovered from the mold mycelia was produced when potato waste materials were homogenized and added to a mineral salt containing a culture medium suitable for the action of a strain of Aspergillus niger.*

*The new product containing approximately 28.0 percent protein was added to chick starting rations, replacing the soybean protein. Sixty-two (62) percent of the protein in the ration were supplied by soybean meal. The length of the feeding trial was four (4) weeks.*

*Results of the feeding trials showed that fungal protein was effective in supporting body maintenance but was ineffective in stimulating growth. Palatability of rations and poor feed consumption were factors contributing to slow growth. However, feed utilization was less of a problem as shown by nitrogen retention trials.*

*Carcass quality, pigmentation, deposition of fat and uniformity in size were similar in all groups.*

*Fungal protein has the potential for use as a source of protein in chick rations. However, additional research is needed to further study such factors as feed consumption, feed (amino acids) utilization and palatability.*



*This report is submitted in fulfillment of Grant Number R802679-01 by Tennessee State University, Nashville, Tennessee, under the sponsorship of the Environmental Protection Agency. Work was completed October 1974.*

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## SECTION I

## CONCLUSIONS

Microbial (fungal) protein produced from potato waste materials was effective in supporting body maintenance in growing chicks but was ineffective in stimulating growth.

The data also showed that feed consumption was a major factor contributing to poor growth. Feed utilization was less of a problem since there was little difference in nitrogen retention between the chicks fed the rations containing all soybean protein when compared to the chicks fed rations containing the fungal protein. Palatability of the diets seemed to have been another factor contributing to slow growth.

The overall carcass quality of the chicks fed the basal and experimental rations was good, even though the chicks fed high levels of fungal protein were small when compared to those fed the basal ration. Pigmentation, deposition of fat and uniformity in size were similar in all groups.

The data indicated that fungal protein produced from potato waste materials has the potential for use as a source of protein in chick starting rations.

## SECTION II

## RECOMMENDATIONS

It is recommended that additional microbial protein be produced from potato waste materials and in combination with other high and low starch waste materials.

It is also recommended that additional research be conducted to further study such factors as toxicity, palatability, feed consumption, feed utilization, protein quality and the grot factor.

In addition to chick studies, other types of poultry such as turkeys, as well as small animals (rats), should be used in feeding trials.

## SECTION III

## INTRODUCTION

The disposal of solid waste, whether from industrial, agricultural or other sources, continues to be a major problem in most areas in the United States. The traditional waste disposal methods of landfills, incineration and dumping into flowing streams have not only been unsatisfactory from a resource recovery standpoint, but are becoming less feasible as more stringent regulations concerning air and water pollution are put into effect. Technological development for acceptable disposal methods and the economical recycling of organic wastes into usable products has been and remains the primary objective of the National Environmental Research Center, Cincinnati, Ohio 45256.

In the past many proposals have been made for the conversion of organic waste materials into useful products ranging from utilization of their intrinsic fuel value, anaerobic conversion to methane, production of chemicals including ethyl alcohol, and the utilization of fermentable substrates to produce edible protein. After evaluating the many recycling alterations, the Solid & Hazardous Waste Research Division has identified, as one promising option, the biological conversion of organic wastes into foodstuff.

Some of the processes developed for the utilization of agricultural and industrial wastes are based on their conversion to single-cell protein (1,2) by using the wastes as substrates on which to grow yeasts

and other fungi and bacteria for animal or human consumption. Food or animal feed is thus produced from a renewable resource without interfering with the primary productivity of agricultural land. Torula yeast (Candida utilis) grown on molasses or sulfite liquor has been long used in animal feed--but in small quantities, primarily as a vitamin source. Processing to lower its nucleic acid content will be required and has been researched (3) to make it acceptable as a significant protein source for human consumption. The same limitation applies to all other single-cell proteins, because rapidly growing cells have a high content of nucleic acid that man can excrete only in the form of uric acid. Too much uric acid leads to its deposit in the joints, causing gout, or in the kidneys, where it may lead to stone formation.

As in the case of higher plants, each new yeast, fungus, or bacterium species proposed for human use will have to be carefully screened for toxicity and allergenicity in man. Careful processing will be required to render them suitable for food use.

There is now much interest in the production of single-cell protein from petroleum hydrocarbons, and their use as food will similarly depend greatly on the ability of the food technologist to render them safe and palatable, and on the food industry to incorporate them into attractive food products. There can be little doubt that single-cell protein, in the broad sense in which the term is currently used to include multicellular lower plants such as filamentous fungi as well as yeasts and bacteria, will make an increasingly important contribution to animal and human feeding. However, the use of single-cell protein, grown on relatively pure substrates and processed for human consumption, seems almost

certain to be initially limited to the processed foods of the industrialized countries because of its high cost compared with that for protein from legumes and oilseeds.

As an alternative to direct human use of single cell protein, a short-term preliminary feed trial with fungal protein produced in the SHWRD laboratory was conducted at Oregon State University Food Science and Technology Laboratory. The fungal protein (50 percent) was incorporated in the feed at a 25 percent level as a substitute for fish meal and fed to young rainbow trout over a period of 2 months. The growth rate of the trout fed this test diet was similar to that of trout fed the control diet. The feeding enthusiasm was excellent, and the animals exhibited no signs of toxicity.

A more extensive fungal protein feeding study with chicks was initiated at Tennessee State University. The purpose of this research was to determine the nutritional value of fungal protein in the diet of broiler type chicks.

## SECTION IV

## EXPERIMENTAL PROCEDURE

The microbial (fungal) protein used in this study was prepared when potato waste or starchy material was homogenized and added to a mineral salt containing a culture medium suitable to the action of a strain of Aspergillus niger. The protein material containing approximately 29.0 percent, was recovered from the mold mycelia, Rogers et al. (1972) (2).

The amino acid composition of the fungal protein compared with several standard proteins is shown in Table I. The nutritional value of proteins depends upon a complement of essential amino acids present. It is apparent from Table I that the fungal protein developed compares favorably with other standard proteins. The product contains all of the essential amino acids required by the chick.

Day-old broiler type chicks were used in this study. The chicks were wing-banded, weighed and distributed at random into five experimental groups (12 chicks per group). All groups were maintained in electrically heated, thermostatically controlled battery brooders equipped with raised wire floors. The chicks received constant lighting and the room in which the broodere were located was heated to provide a minimum temperature of 70°F. Ventilation was provided by thermostatically controlled exhaust fans. Individual chick weights and group feed consumption were recorded at bi-weekly intervals during the

experimental period and feed efficiency was calculated at the end of the experiment. Feed and water were supplied ad libitum. Mortality was recorded on the day of occurence, and only surviving chicks were included in the statistical analysis. The length of the feeding period was four weeks. Management of birds in the battery was in keeping with good poultry practices.

Experimental Rations

One basal ration of the corn-soybean meal type in combination with other ingredients commonly employed in poultry feeding was computed. Approximately 62 percent of the total protein in the basal ration was supplied by soybean meal. Four subsequent rations were calculated replacing 25, 50, 75 and 100 percent of the soybean meal protein with fungal protein (Table II).

Analysis of Data

The criteria used for determining the effectiveness of the new protein were (1) average body weight; (2) average gain; (3) feed efficiency, freedom from diseases; (4) mortality and (5) nitrogen balance trials.

The body weight data were subjected to statistical treatment by the analysis of variance, Snedecor (1956) (4). When a significant difference due to treatment was made by computing the L.S.D. (least significant difference). The L.S.D. represents the minimum increase or decrease in body weight required for significance at the five percent level of probability.

*Nitrogen Balance Trials*

*Nitrogen retention tests, conducted to measure the utilization of the experimental diets by the chicks, were performed by the indirect method involving the analysis of diet and excreta. Special wire cages holding six to eight birds were placed on battery wire floors. Porcelain trays measuring 12" x 18" x 2½" that fitted conveniently under each cage were used as receptacles for the feces. In order to prevent the loss of nitrogen to the atmosphere, 1.5 liters of a 1 normal solution of sulfuric acid were placed in each receptacle. At the end of the two-day test period, the acid mixtures were transferred to tared gallon jars and weighed. The total nitrogen excreted was determined by mechanically stirring the acid mixture to form a uniform slurry from which a sample of approximately 500 ml. was transferred to a Waring blender and completely homogenized, after which a 20 to 30 ml. aliquot was weighed into a digestion flask, and the nitrogen was then determined by the AOAC*method. The individual chick weights and the feed consumption were recorded for the test period. Kjeldahl nitrogen (AOAC) values were also obtained on the samples of feed used. The nitrogen retained by the birds was calculated as the difference between the nitrogen values in the feed samples and the total nitrogen content of the feces excreted during the test period.*

*Due to the amount of material available, the study was limited to broiler type chicken rations.*

*AOAC - Association of Official Agricultural Chemists

TABLE I

AMINO ACID ANALYSIS OF A FUNGAL STRAIN COMPARED TO SEVERAL STANDARD PROTEINS

(Grams/16 Grams Nitrogen)

| Amino Acid | Aspergillus Niger on Potato Waste | Casein | Soybean Meal | Opaque-2 Corn |
|---|---|---|---|---|
| Lysine | 4.2 | 8.0 | 6.6 | 4.2 |
| Histidine | 1.8 | 3.0 | 2.5 | 3.5 |
| Arginine | 4.7 | 4.0 | 7.0 | 6.8 |
| Aspartic Acid | 9.4 | 7.0 | 8.3 | 10.0 |
| Threonine | 4.8 | 4.7 | 3.9 | 3.3 |
| Serine | 4.7 | 6.7 | 5.6 | 4.3 |
| Glutamic Acid | 10.5 | 25.0 | 18.5 | 18.7 |
| Proline | 4.4 | 11.0 | 5.0 | 8.6 |
| Glycine | 5.0 | 2.5 | 3.8 | 4.8 |
| Alanine | 4.3 | 3.0 | 4.5 | 6.5 |
| Cystine | 0.8 | 1.0 | 1.2 | 1.7 |
| Methionine | 3.2 | 3.5 | 1.1 | 1.4 |
| Valine | 6.5 | 7.7 | 5.2 | 4.9 |
| Isoleucine | 5.3 | 6.5 | 5.8 | 3.2 |
| Leucine | 8.6 | 9.7 | 7.6 | 8.4 |
| Tyrosine | 4.4 | 6.5 | 3.2 | 3.9 |
| Phenylalanine | 7.7 | 5.9 | 4.8 | 4.4 |
| Tryptophan | 1.2 | 1.2 | 1.2 | 1.3 |

*TABLE II*

*COMPOSITION OF THE RATIONS*

| *Ingredients (in percentage)* | *Basal* | *25% Fungal Protein* | *50% Fungal Protein* | *75% Fungal Protein* | *100% Fungal Protein* |
|---|---|---|---|---|---|
| *Ground yellow corn* | 56.50 | 52.575 | 48.650 | 45.725 | 40.80 |
| *Soybean oil meal (44% protein)* | 30.00 | 22.50 | 15.00 | 7.50 | -0- |
| *Fungal protein (28.88% protein)* | -0- | 11.425 | 22.850 | 33.275 | 45.70 |
| *Meat and bone scraps (50% protein)* | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| *Menhaden fish meal (60% protein)* | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| *Dried whey product* | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| *Dehydrated alfalfa meal (17% protein)* | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| *Dicalcium phosphate* | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| *Limestone, ground* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| *Salt, iodized* | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| *Premix* | 0.50 | 0.50 | 0.05 | 0.50 | 0.50 |
| *Percentages, Crude Protein* | 21.44 | 21.50 | 21.125 | 21.125 | 20.70 |

## SECTION V

## DISCUSSION

The results of the treatments are shown in Table III and Figure I. The basal ration contained 21.44 percent crude protein. Of this amount, 62 percent of the protein was supplied by soybean meal. Treatment rations were calculated replacing the soybean meal protein in the rations with equivalent fungal protein at 25, 50, 75 and 100 percent levels.

The data show that the average body weight of the birds in the experimental groups was significantly less than those in the control group ($P < .05$). When the average body weight of the birds in the experimental groups was compared a significant difference was observed between the groups fed rations in which the soybean protein was replaced by 25 and 50 percent fungal protein and those fed rations containing 75 and 100 percent fungal protein. However, there was no significant difference between the average body weight of the birds fed the rations containing the 25 and 50 percent fungal protein.

The data also show that the birds fed the ration containing 100 percent fungal protein made the poorest gain in body weight. However, mortality was low and the marketing qualities of the birds were good. Pigmentation, deposition of fat and uniformity in body size were also good. These observations indicate that the ration provided the essential nutrients to support body maintenance and fat production but not growth. Adequate utilization of the fungal protein by the chicks seemed

not to have been a problem. On the other hand, feed consumption and/or absorption may have been problems. The diet in which 62 percent of the total protein was supplied by fungal protein also contributed to the production of body fat as well as the general overall appearance of the dressed birds.

Palatability of the rations was another factor to consider in the evaluation of chick growth. Chicks fed rations in which the soybean protein was replaced by 50, 75 and 100 percent fungal protein consumed considerably less feed.

Particle size was a factor that may have affected feed consumption. The texture of the fungal protein supplement resulted in a powder form when ground and was very light in weight. The chicks had a tendency to pick out the large feed particles and to leave the finely ground materials.

Nitrogen Retention Trials

A criterion for the evaluation of the nutritive value of a feed is the efficiency of its utilization when fed to growing chicks. The efficiency of utilization is affected by the amount of nutrients retained in the body of the birds. The results of the nitrogen retention trials, shown in Table IV, indicate little variation in the retention of nitrogen in chicks fed the basal of the experimental rations. However, much more variation existed in feed consumption. Feed consumption decreased proportionally as the level of fungal protein increased in the rations. In view of these findings, factors affecting feed consumption may have contributed more to poor growth than feed utilization.

Due to the limited amount of available fungal protein materials, palatability and toxicity were not studied.

TABLE III

EFFECT OF FUNGAL PROTEIN ON CHICK GROWTH AND FEED UTILIZATION (In Grams)

| Rations | Average Weight 4-Weeks | Ave. Gain | Weight Difference Due to Treatment | Required L.S.D. | Feed Conversion | Survivors at 4-Weeks |
|---|---|---|---|---|---|---|
| Basal | 401.0 | 371.0 | | | 1.14 | 11-12 |
| Fungal Protein 25% | 312.0 | 290.11 | - 80.0 | 31 | 2.47 | 11-12 |
| Fungal Protein 50% | 301.00 | 278.40 | - 92.61 | 31 | 1.84 | 11-12 |
| Fungal Protein 75% | 211.3 | 180.31 | -190.3 | 31 | 3.00 | 9-12 |
| Fungal Protein 100% | 113.37 | 81.13 | -289.87 | 31 | 5.40 | 12-12 |
| Commercial Chick Starter | 334.8 | 303.22 | - 68.9 | 31 | 2.21 | 12-12 |

FIGURE I

EFFECT OF FUNGAL PROTEIN ON
GROWTH RATE OF CHICKS (Four Weeks)

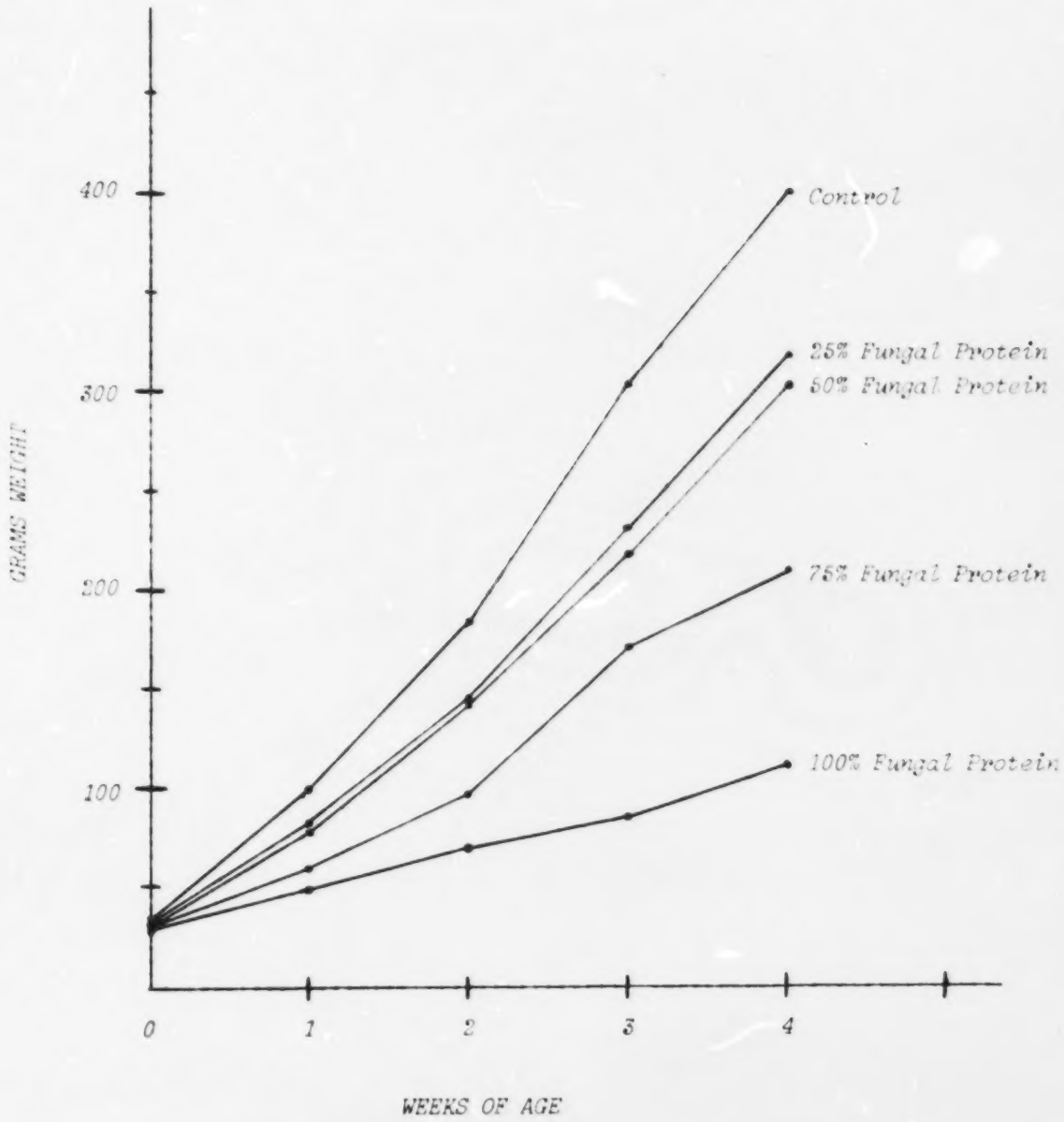

TABLE IV

EFFECT OF FUNGAL PROTEIN ON THE
RETENTION OF DIETARY NITROGEN BY THE CHICK (In Grams)

| Rations | Total Gain Four Weeks | Gain, N. R. Trials* | Total Nitrogen in Feed | Total Nitrogen in Feed | Percent Nitrogen Retained |
|---|---|---|---|---|---|
| Basal | 371.0 | 41.6 | 36.4 | 16.5 | 54.67 |
| Fungal Protein 25%** | 290.0 | 23.0 | 36.6 | 16.4 | 55.19 |
| Fungal Protein 50% | 273.46 | 21.0 | 36.1 | 16.6 | 54.02 |
| Fungal Protein 75% | 180.51 | 1.2 | 35.6 | 16.4 | 53.93 |
| Fungal Protein 100% | 82.19 | 0.7 | 34.5 | 16.4 | 52.46 |

*Gain during nitrogen retention trials

**Replacing 25, 50, 75 and 100 percent of protein supplied by soybean meal in basal diet

## SECTION VI

## REFERENCES


Callihan, C. D. "Construction of Continuous Chemical-Microbial Pilot Plant to Produce Edible Proteins from Cellulosic Waste," Contract No. PH-86-68-152. Baton Rouge: Louisiana State University, 1968.

Rogers, C. J. et al. "Production of Fungal Protein from Cellulose and Waste Cellulosic," Environ. Sci. Technol. No. 6, 8 (August 1972).

Daly, W. H. "Fabrication of Single Cell Protein from Cellulosic Waste," Grant No. EP-00524. Baton Rouge: Louisiana State University, 1970.

Snedecor, G. W. Statistical Methods, 5th ed. Ames: Iowa State University Press, 1965.

Horwitz, William (ed.). AOAC Methods, 11th ed. Washington: Association of Official Analytical Chemists, 1970.